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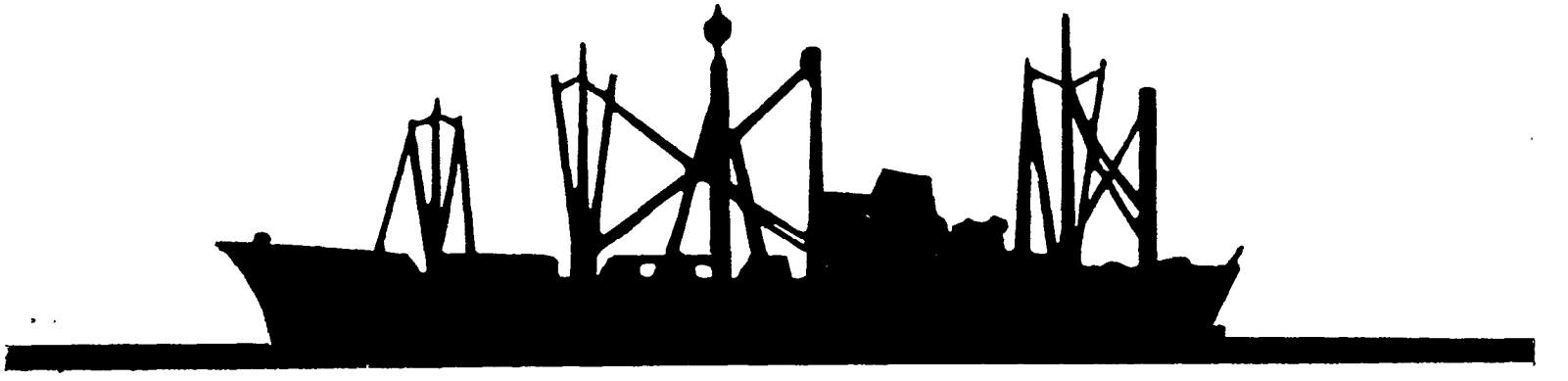

INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

I R E A P S

# IMPROVING SHIPYARD PRODUCTIVITY BY SUBCONTRACTING MATERIAL AND LABOR WITHIN SHIPYARDS

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## ABSTRACT

It can be taken as true that an organization which specializes in one area produces at lesser cost than an organization which, in one plant, produces and assembles in substantially different areas. Shipyards which manufacture and assemble many different products recognize the advantages of specialization; they try to purchase materials and equipment in as finished form as available for further assembly and installation. In some areas shipyards go further and subcontract the installation of material directly into ships.

The thesis proposed here is that the productivity of U.S. shipyards would be increased and ships would cost less if a deliberate policy of extensive subcontracting of material and its installation labor within shipyards were adopted. In time, shipyard staff would become primarily specialized efficient organizations which coordinate the work of specialized, independent contractors. The organizations would be the same in principle as those which have developed for most large, land-based construction.

The discussion explores the promise of this change from present practice. How would it apply to traditional and newer preoutfitted modular construction and its effect on the labor force of shipyards? Some of the discussion is based on the author's many years of experience working for a company which was a subcontractor for material and labor within large and small shipyards in the United States.


## ACKNOWLEDGMENT

Discussions I had on this subject with Mr. John J. McGowan, Chief, Division of Cost Estimates, U. S. Maritime Adminstration, helped define my views. I benefited from his experience and insight.


## INTRODUCTION

### REASONS FOR SUBCONTRACTING

A shipyard subcontracts when it assigns some portion of its contract effort to another firm without giving up its responsibility for the work subcontracted. It is a contract secondary to the prime contract between yard and owner. The term is generally understood to apply when the labor component is a significant fraction of the value of the secondary contract. In this discussion the term is used to include the purchase of any ship components which a yard with varied production facilities is capable of assembling or installing itself. Thus, I will depart from the restrictions of the title to include as subcontracts purchase of ship components which require a large labor component. Examples of subcontracts are: bitts and chocks, a skid-mounted pre-piped refrigeration unit, or services to furnish material and labor to install deck covering on a ship. Also, the discussion applies principally to those yards which could do that which they subcontract. Thus small yards are excluded.

Another way to look at subcontracting is that it is the "buy" decision resulting from a "make" or "buy" analysis. The considerations leading to the "buy" decision would have included:

a. The parts or services would be acquired at less cost than the total cost of yard labor and overhead applied to the purchase.

b. Manufacturing facilities are not available or facilities are committed to other work.

C. Manpower is insufficient or committed to other work.

d. The work is new and the yard has no experience with it.

e. The work is expected to be a one time effort so that learning and tooling is not justified.

f. The work is not related to building a ship. Addition of a new building or installation of specialized equipment are examples.

g. Other reasons, some of which are evident by naming some equipment or parts: electrical equipment, electronics equipment, and fasteners. Why these are not made would be answered by the observation that "the yard is in the business of building ships, not parts."

The first of the foregoing factors is the only one for which a serious make or buy decision is debated. The other factors virtually dictate "buy."

I believe that there is another reason behind each of the stated reasons, and that is that subcontracting increases shipyard productivity. That underlying reason is probably rarely expressed or explored. The purpose of this discussion is to do so.

DEFINITIONS OF PRODUCTIVITY

Two definitions are needed:

a. Productivity is defined by the ratio, output per man hour. One method is more productive than another if more output results from the same number of man hours, or if fewer man hours are required for the same output.

b. Productivity is equivalent to efficiency, and can be defined as the ratio of dollars:

$$\text{Productivity} = \text{efficiency} = \frac{\text{output dollars}}{\text{input dollars}}$$

$$= \frac{\text{profit}}{\text{material} + \text{labor} + \text{overhead}}$$

In the foregoing ratio, yard profit is that anticipated or targeted. It could be that for a single contract or for the total yard operations per year. The denominator is the total of expenditures anticipated for the contract or year. If this total can be reduced through another method of operation then productivity is increased.

## OBSERVATIONS AND PREMISES

### OBSERVATIONS

Some general observations about our common experience are in order. Two premises which stem from these observations will then be stated.

a. The first observation comes from the nonresidential construction industry, specifically that which builds office buildings of thirty or more stories. The builder is a general contractor who contracts virtually all the input to complete the structure. Beginning with the site survey and proceeding toward completion he organizes and schedules the work of different subcontractors who separately, but in parallel and series do: excavation, foundations, concrete, structural steel, electrical work, heating and air-conditioning, plumbing, glazing, and waterproofing. When the building is almost complete, still other specialists take over: interior partitions, painting, flooring, office layout, draperies, locksmiths, even sign painters. Then still other specialists move in: rental agents, employment agencies, building managers, energy managers, cleaning services. Is a ship any less complex than a building, not to benefit from specialists?

b. Below is a list of items which have been subcontracted by yards. Most yards have the organization and plant to do some of these items but chose not to.

Engineering services
Computerized lofting and plate layout
Heavy lift services
Insulation, hull, machinery, and piping
Joiner work, installation aboard ship
Joiner work, completely outfitted modular staterooms
Completely outfitted deck houses
RO-RO gear of all kinds
Hatch covers
Large hull steel subassemblies made in one yard and carried by barge over long distances
Tank blasting and painting.

C. The advantages of specialization by yards and organizations within the shipbuilding industry are evident in the appearance of yards which concentrate on large ocean barges, those which specialize in tugs and offshore boats, and those which specialize in drilling rigs. If they have appeared there must have been economic justification for them.

d. My own experience working for an organization which was a subcontractor to the shipbuilding industry has been favorable. Eastern Cold Storage Insulation Company subcontracted materials and labor in the areas of insulation, joiner work, and related materials of all kinds for commercial and naval ships in many shipyards of the United States. I came away with the conviction, stemming from long intensive experience that our work contributed to the productivity of each yard from which we received contracts.

A last general observation is important The estimate for aeshipbuilding contract predicts the material and labor costs and profit expected for the contract. All the estimators agree that material costs are much more accurately predicted than labor costs. At the end of a shipbuilding contract estimated versus actual costs are compared. It is almost always found that through all the rocky road of actual construction estimated material costs have been pretty close to target. Labor costs, on the contrary, have been too frequently underestimated. Since subcontracts are material their usefulness is evident.

## PREMISES

From these observations two premises follow. The first relates to the first definition of productivity and reflects the experience of all of us outside as well as inside the shipbuilding industry. Indeed it is not a premise but a truism since our society is so organized: Specialists are more efficient, that is more productive than non-specialists. For a given number of hours they will produce more.

The second premise relates to the second definition and is the one to be discussed in the balance of this paper: The productivity of the relatively large shipyards which build a variety of ships can be increased if they subcontract to a greater degree than they do now. Subcontracting will reduce their total expenditures for material and labor and overhead and therefore increase their productivity. In other words, as the components of the denominator become more material dollars and fewer labor and overhead dollars, shipyard productivity will increase.

## EXAMINATION OF THE PREMISES

### ESTIMATE FOR A 40,000 DWT BULK CARRIER

We start by examining part of an estimate for a 40,000 DWT bulk carrier built in the United States. It is not an actual estimate but one which is assumed and is believed to be'

## 40,000 DWT Bulk Carrier

### Principal Direct Material and Labor Costs

### Part 1 - Material Purchased Substantially Assembled and Subcontracted Material

| MARAD Cost Group | Description | Material Dollars 000's | Labor Hours 000's | Labor Dollars (Hrs.x$25) 000's | Labor Dollars as Percent Material Dollars |
|---|---|---|---|---|---|
| 5 | Hatch Covers | $ 1,675 | .5 | $ 13 | 1 |
| 25 | Main Engine | 6,000 | 6.0 | 150 | 2 |
| 21 | Cargo Cranes | 2,575 | 3.0 | 75 | 3 |
| 28 | Steam Generating Plant | 575 | 1.0 | 25 | 4 |
| 7 | Anchors and Chains | 400 | .8 | 20 | 5 |
| 14 | Windlasses, Steering Gear | 725 | 3.0 | 75 | 10 |
| 8 | Lifesaving Equipment | 200 | 1.0 | 25 | 13 |
| 10 | Joiner Work | 1,700 | 10.0 | 250 | 15 |
| 39 | Central Machinery Control | 500 | 3.0 | 75 | 15 |
| 23 | Radio and Electronics | 825 | 5.0 | 125 | 15 |
| 37 | Machinery Space Outfit | 75 | .6 | 15 | 20 |
| 11 | Deck Coverings | 75 | .6 | 15 | 20 |
| 17 | Refrigeration Systems | 150 | 2.5 | 63 | 42 |
| 26 | Shafting, Propeller | 675 | 12.0 | 300 | 44 |
| 33 | Distilling Unit | 75 | 1.5 | 38 | 58 |
| 36 | Compressed Air and Gas | 225 | 6.0 | 150 | 67 |
| | Subtotal Group 1 | $16,450 | 56.5 | $ 1,412 | |
| | Percent of Total | 56 | | 6 | |

### Part 2 - Other Material and Labor

| | | | | | |
|---|---|---|---|---|---|
| 29 | Fuel Oil Service | $ 275 | 1.5 | $ 38 | 14 |
| 34 | Sea Water System | 350 | 3.5 | 88 | 25 |
| 35 | Fresh Water System | 110 | 1.5 | 38 | 34 |
| 32 | Lube Oil System | 375 | 8.0 | 200 | 53 |
| 22 | Electricity | 2,250 | 75.0 | 1,875 | 83 |
| 18/20 | Hull Piping Systems | 1,725 | 75.0 | 1,875 | 109 |
| 12 | Utility Outfit | 150 | 7.0 | 175 | 117 |
| 30 | Steam and Exhaust Systems | 150 | 8.5 | 213 | 142 |
| 1 | Steel | 6,325 | 475.0 | 11,875 | 188 |
| 4 | Hull Fittings | 200 | 18.0 | 450 | 225 |
| 27 | Air Intake - Exhaust Uptake | 50 | 6.0 | 150 | 300 |
| 9 | Masts and Rigging | 25 | 3.0 | 75 | 300 |
| 24 | Painting | 725 | 100.0 | 2,500 | 345 |
| 15 | Air Conditioning | 200 | 28.0 | 700 | 350 |
| 40 | Machinery Space Ventilation | 125 | 20.0 | 500 | 400 |
| 3 | Staging, Shoring, Cribbing | 125 | 30.0 | 750 | 600 |
| 38 | Machinery Space Access | 25 | 10.0 | 250 | 1,000 |
| | Subtotal Group 2 | $13,185 | 870.0 | $21,750 | |
| | Percent of Total | 44 | | 94 | |
| | Total Direct Cost | $29,635 | 926.5 | $23,162 | |
| | Total Percent | 100 | | 100 | |

representative of such ships and other ship types built in the kind of yards we are discussing.

Table I shows the principal direct material dollars and labor plus overhead costs in hours and dollars (at $25 per hour) required to build the ship. Small items have been omitted. The item numbers and corresponding description identify MARAD cost groups. All the groups are then divided, for this analysis, into two parts. Part 1 consists of material purchased substantially assembled and of subcontracted material. Part 2 consists of all other material. Together both parts include virtually all the items which are physically present on the completed ship. Supporting costs such as crane services, cleaning services, launching, docking, trials, insurance and fees are not shown. For such support, as a percent of the total of Parts 1 and 2, material costs would be about 5 percent of the direct material, and labor costs about 25 percent of the direct labor. Engineering costs would be about 11 percent of the first ship costs, if the design were new.

Within each Part the items are listed in the order of the lowest ratio of the number of labor dollars expended in the shipyard to install the number of material dollars purchased. The lower the ratio the less the shipyard labor input. This bears on the premise expressed above, fewer labor and overhead dollars for the denominator of the productivity ratio.

The division between Parts 1 and 2 of the Table is not part of the MARAD cost system but has been made only for this paper.

A condensed version of Table I is:

| | | Dollars | |
|---|---|---|---|
| Part | Description | Material | Labor and Overhead |
| 1 | Material purchased substantially assembled and subcontracted material | $16,500,000 | $ 1,412,000 |
| 2 | Other material | $13,185,000 | $21,750,000 |
| | Total | $29,685,000 | $23,162,000 |

| | | Percentages | |
|---|---|---|---|
| Part | Description | Material | Labor and Overhead |
| 1 | Material purchased substantially assembled and subcontracted material | 56% | 6% |
| 2 | Other material | 44% | 94% |
| | Total | 100% | 100% |

The second version is to be particularly studied. Only 6 percent of the direct labor and overhead needed to build the ship is expended on items purchased substantially assembled or subcontracted. 94 percent of the labor is expended on items acquired in pieces. The value of the material dollars is equally significant. Six percent of labor installs 56 percent of the material cost of the ship, while 94 percent of the labor cost is expended on 44 percent of the material cost.

The impact of the foregoing percentages appears persuasive. Materia1s in Part 1 require minimum yard labor. Would it not follow that as materials are moved from Part 2 to the classification of those in Part 1, "Purchased substantially assembled and subcontracted material" that productivity of shipyards would increase? We will examine the ramifications of that conclusion.

ADVANTAGES OF SUBCONTRACTING

The advantages of subcontracting material and labor both outside and inside the yard include:

Uncertain future labor dollars are converted into fairly predictable material dollars. This means that the probability of achieving the expected profit on the contract is significantly increased.

b. The task of running the labor force is reduced. To get an idea of the advantages consider a yard with the same dollar volume of business but with say one-quarter to one-half less workforce to handle.

c. Less investment in capital equipment will be needed.

d. Less material inventory will be needed.

e. Fewer purchase orders need to be issued and tracked.

f. Since subcontractors are specialists, improved quality of output can be reasonably expected and there is increased likelihood that yard schedules will be met.

g. There is more stability of yard employment. Typical conditions where there is work for the steel shop but little for the outfitting shops, or later, when the outfitting shops are busy but there is no work for the steel shops would be lessened.

h. Subcontracting, if sufficiently implemented, will make yards better prepared to change with the times. It will be easier to build new ship types and more diverse ships may be contracted for because the yard will be less committed to fixed plant and assembly skills. Good organizational and scheduling skills which it will have specialized in will provide the necessary flexibility to take advantage of new opportunities.

OBSTACLES AND DISADVANTAGES OF SUBCONTRACTING

There are valid arguments against subcontracting.

a. Shipyards already are specialists. This argument impinges directly on the premise that subcontracting is taking advantage of specialization and results in less labor to build a ship. The argument continues that the yards under discussion already are specialists and that the degree of specialization they represent is about as fine as practicable. After all, most shipyards produce mostly ships although they could produce railroad cars.

b. The argument allied to the one above goes thus: The shipyards are now composed of a group of specialists whose work is organized and scheduled centrally. This group of specialist departments, structural, electrical, pipe, paint, machinists, and others are run by very competent staffs who are accustomed to working with each other. Together, for a given task they can, it is asserted, produce with fewer labor hours than any group of subcontractors. It may be said that they represent the economic optimum of each specific yard after each has come to the stage of subcontracting represented by the material of Part 1 of the estimate discussed above. This is a strong argument and expresses reality for each yard. Its departments and shops are specialists, staffed at the management levels with men of long, hands-on experience building ships. They are dedicated to their work and to the shipyards which employ them.

C. To consider the foregoing argument, take one example. Table 1 shows that Cost Group 1, Steel, totals 475,000 hours to fabricate, assemble, erect, and weld the hull and super-structure. Now consider that production rates for the same

type of steel work for multiple ships vary among yards from 50 to 90 man hours per ton. If a yard which produces at say 70 hours per ton were to buy subassemblies from one producing at say 55 hours it would save 20 percent of its direct steel labor. In this instance a substantial savings of 100,000 direct hours and 125,000 direct plus support hours would result. Thus, despite yard departments being specialized they are not necessarily as productive, or as efficient, as the work permits. One reason is that the investment in tooling for the same shops varies among yards. Another is that shipyard departments are not independent, their efficiencies being affected by other departments. Still another reason is that many yard departments work intermittenly at low capacity rather than continuously at high capacity.

d. Yards have substantial investment in material handling equipment, drydocks, piers, storage and administration buildings, and machinery such as welding equipment. In addition there is a substantial investment in shop buildings and the tools housed in them. In total, these investments may well weigh against subcontracting, but they should be viewed individually. All the facilities except shop buildings and tools would probably still be needed even in an extensive subcontracting program. They would continue to be carried in the overhead account. Shop buildings and tools would continue to be used but less intensively and could be accounted for on a depreciated basis rather than on a replacement cost basis. One method of taking the investment in existing plant into account when deciding on subcontracting is given below.

Union agreements usually stipulate that work within the yard may not be subcontracted without concurrence by the unions. In the past unions have not objected to "Furnish and Supervise*' subcontracts. In such subcontracts which are fixed in amount for both material and labor the subcontractor draws his labor, except for supervision, from the yard force which remains on the yard payroll. Hours in excess of an agreed amount are charged to the subcontractor. This arrangement has been satisfactory to both subcontractor and yard. The disadvantage that the workforce is not wholly responsible to the subcontractor is compensated by the subcontractor drawing only the number of men he needs and, under the informal understandings prevalent in yards, choosing only the men he wants.

f. Once a contract has been signed with a subcontractor the yard becomes dependent on his performance. If the subcontractor fails to deliver the yard has to seek a substitute or be prepared to do the work itself. However, the record of subcontract performance in the shipbuilding industry, when reputable subcontractors were selected, has been good.

## A CRITERION FOR SUBCONTRACTING

Although the advantages and disadvantages of subcontracting are clear, they are difficult to quantify. Frequently, the best decisions are those which are made on the basis of convictions, or hunches, or verbal rationalizations. Yet, since decisions are usually shared or need to be explained to others, those which are based on the simple criterion of dollar savings frequently are those which are selected.

An example of such reasoning, much simplified, is given below. It compares the cost of doing the work by the shipyard organization with the cost of a subcontract. In practice, cost estimates by a yard for its own performance may be optimistically low in order to avoid subcontracting.

The example uses a work package which by yard estimate requires $400,000 in material, $200,000 in direct labor, and $200,000 in overhead.

| | Not Subcontracted | Subcontracted |
|---|---|---|
| Material | $400,000 | 0 |
| Labor, direct, including engineering | 200,000 | 0 |
| Overhead, percent of direct labor | | |
| Fringes on direct labor, 30% | 60,000 | 0 |
| Indirect labor, including fringes 30% | 60,000 | |
| Depreciation, 7% | 14,000 | $14,000 |
| Other fixed costs, 33% | 66,000 | 66,000 |
| Total | $800,000 | $80,000 |
| Subcontract | | |
| Contract value | | $680,000 |
| Services, to subcontractor, say | | 40,000 |
| | Total | $800,000 |

In the foregoing, if no dollar value is placed on the advantages of subcontracting, and if indirect labor and other fixed costs are considered unchanged by subcontracting, and if in addition the subcontract is charged some amount for services such as power, cleaning, etc. then the break even price for the subcontract is $680,000 or 15 percent less than the cost to the yard.

In practice each yard will decide for itself the individual charges for each alternate. Because such allocations are rarely known with confidence and the desired answer may influence them, the responsibility for initiating and deciding all "make or buy" alternates should be with the individual responsible for the profitability for the yard.

## PRODUCT WORK BREAKDOWN CONSTRUCTION AND SUBCONTRACTING

### PWBS AND ZONE OUTFITTING

Popular current terms which apply to ship construction are Product Work Breakdown Structure, Hull Block Construction, and Zone Outfitting. The objective is an increase in productivity,' to be achieved by doing *as* much work as possible on individual ship sections which are assembled in rapid sequence to form a complete ship. The concept and practice are not new. What is new is the systematic planning and determination to produce the ship in individual zones and larger sections each of which are individually substantially complete before they are joined.

These methods will improve yard productivity. Will they do so to the degree that subcontracting will not be needed? I think that the following observations are valid:

a. The Old-new methods will increase productivity within present yard organizations.

b. It appears each yard will continue to do most of the work with its force and within its shops.

C. It is too early to conclude whether or not these methods will make the yard departments specialists to the degree that outside subcontractors can become specialists in this method of construction.

d. Because the methods are predicated upon the ships to be assembled from building blocks, the opportunities for subcontracting may be increased rather than diminished. It is conceivable that a yard may buy all of its subassemblies and zoned units from others and finish and assemble them with a minimum work force of assembly specialists.

As pointed out earlier, production rates for steel vary among shipyards. Purchase of steel units by one yard from another, involving long distance barge transportation has been common. Such practice, generated by necessity rather than from deliberate policies of subcontracting, may well be viewed from the latter point of view by a yard committed to the new methods. Some yards can construct steel in the range of 40 to 60 man hours per ton but river barge yards appear to produce at rates

substantially less. With modular design of units it will be possible to take advantage of the assembly line production facilities of river barge yards and use the rivers as conveyor belts to bring completed units to final assembly points.

The zone system of outfitting appears consistent with the use of subcontractors who work either within or outside the yard. Of the three zone outfitting options, on-unit, on-block, and on-board, only the on-block unit requires a hull steel section as a working platform. Subcontracting would emphasize on-unit installations which naturally precede on-block installations. On-unit assemblies are being provided now without being so formally labeled. That each unit encompasses pipefitting, electrical work, painting, and other skills is not a disadvantage because such work is not assigned to separate crafts in the subcontractor's plant. Installation of these units by the same or other subcontractors on the zone blocks or on board ship would be the same as using vendors' supervision of yard personnel for the same purpose, a very common practice now. An obvious advantage of on-unit assemblies is that a few contractors can and do serve relatively many yards. Recall that complete deck houses are being built off the hull and lifted into place when completed. If that can be done within one yard then such deck houses can be built outside the yard by a single subcontractor to several shipyards. A similar practice for ship zones below the main deck, with completed zones being provided to shipyards should be equally feasible.

## CONCLUSIONS

The extensive subcontracting which I advocate is a major departure from the current practice of most shipyards, particularly at this time when many are already changing their manufacturing procedures. Yet, the concept has much merit. Consider that much of the work now subcontracted was once done by each yard. Clearly there were advantages to having others do the work. Additional subcontracting need not be done abruptly; most changes are better when they are gradual. But the increase in productivity will be determined by the pace of the change, if I am correct in my thesis.

The discussion presented does not exhaust the subject. Others should contribute so that the benefits of specialization as applied to the shipbuilding industry may be thoroughly explored. A particularly intriguing subject for discussion would be to plan a new shipyard based wholly on subcontracted zones. The new yard would be solely an assembly plant, perhaps the first true assembly line for manufacture of ships.